

"As this particular solution had been standing undisturbed and unchanged for a month before the evaporation was begun, the apparent settling of the metal is not due merely to the lapse of time. Again, it cannot be due to the concentration of electrolytic impurities in the sol, because these were not sufficient to have any appreciable effect, as is shown by the mobility determination for the first three samples." (5)

The only conclusion that can be drawn from these experiments is that fundamentally these suspensions of fine particles always reach a uniform distribution throughout the body of the liquid, and the variation expressed in Perrin's distribution law must be confined to a very small distance at the surface.

REFERENCES.

- (1) Perrin, 'Atoms,' tr. by Hammick (Constable, 1916).
 - (2) *Loc. cit.*, p. 90 *et seq.*
 - (3) *Loc. cit.*, p. 99.
 - (4) Burton, 'Phil. Mag.,' (6), vol. 12, p. 476 (1906); 'Physical Properties of Colloidal Solutions' (Longmans), p. 120.
 - (5) Burton, "On the Physical Aspect of Colloidal Solutions," 'University of Toronto Studies,' No. 36, p. 48 (1910).
 - (6) Bancroft, 'Jour. of Phys. Chem.,' vol. 18, p. 558 (1914).
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A New Form of Interferometer.

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The Lummer and Gehrke interferometer consists of a thin plate of glass with its two surfaces worked optically true and paralalled to one another. High accuracy is required in the plane parallelism, and the flatness of surface and the difficulty of working such long plates for high resolving powers, and the cost involved, sets a limit to our achievement in this direction. Such plates, even when finished, furnish results which have given rise to a considerable amount of discussion and raise doubt as to whether the appearances are trustworthy at such high resolving powers and whether they are not partly due to ghosts formed by the defects in the glass. Hence the present attempt to devise a parallel plate that would meet these objections and serve as an instrument of resolving power and precision sufficient to extend our

knowledge of the constitution of spectrum lines, and a variety of other phenomena requiring the aid of very high resolving power.

The late Lord Rayleigh* used the free surface of a sheet of water as a true optical flat for testing plane surfaces, and describes the results of observations of interference with large differences of path between two interfering beams in a thick slab of water floating on mercury. The optical flatness of the surface of a liquid at rest suggests that, by floating a layer of water or other transparent liquid over another, like mercury, with which it does not mix, we can get an optically perfect plane parallel plate, of any length and thickness, which may be used as a parallel-plate interferometer. The following is a brief account of the results of a series of experiments, conducted under great experimental difficulties during 1918-1919, to test the practicability of this idea.

The light used was that of a glass mercury-vapour lamp, filtered through a green filter to get the intense monochromatic radiations of wave-length $5460\cdot7$ Å.U. Analysis of the light transmitted by this filter showed that the two yellow lines were still present faintly, while the other lines were practically eliminated. Lamps of convenient form were successfully constructed by the writer.

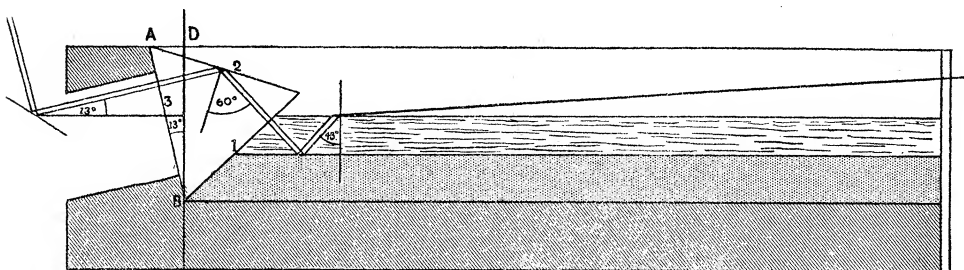
The first experiments were made with a layer of water about 1 cm. deep, floating on mercury. The collimated light, entering the water surface normally, was reflected by an adjustable mirror mounted in the liquid, so as to be incident on the upper surface at the proper angle to ensure a large number of reflections within the layer. The emergent beams of rays were caught in a telescope and examined for the formation of the system of interference bands.

To eliminate troubles arising from tremors on the surface of the water, the experiments were made in the basement cellar of the laboratory at Madras. The apparatus was enclosed in a case to exclude draughts, and the trough was mounted on elastic cushions, placed over a specially designed massive platform resting on rubber corks. But still the water surface was not quiet enough for the purpose in view. When a layer of clear castor oil was used, the surface was found to be more steady, but yet the bands were not visible, though the optical conditions appeared to be satisfied. Further consideration showed, however, that the reflections at the lower and the upper surfaces of the liquid were taking place under such different conditions that the formation of a sharp system of bands was not to be expected, unless the light was polarised in or perpendicular to the plane of incidence. When a nicol prism, suitably orientated, was interposed in the path of the light, the bands

* 'Collected Papers,' vol. 4, p. 56.

became clearly visible. The surface was found to be much more steady in the quiet hours of the morning, and with short exposures it was found possible to photograph the fringes. The poor transparency of castor oil, however, made high resolving power unattainable. After a good deal of further experimentation, means were devised to overcome the disturbing effects of the surface tremors of the ground, efficient enough to make the employment of a layer of water possible, and a mount was designed to carry the trough containing the liquids which would not communicate the surface tremors of the ground. The final arrangement consists of a brick pillar built on a massive foundation considerably beneath the level of the ground in the cellar, the stone slabs forming the floor not being in contact with the pillar. On the top of this pillar rests a massive porcelain trough, containing water in which floats a platform that is prevented from coming into contact with the sides of the porcelain trough. This platform carries a massive levelling table, supported on rubber corks and covered with a few layers of felt. On the top of the felt the trough carrying the liquids is placed. Thin copper wires, attached to the platform, and led over small pulleys on the ceiling to a keyboard on the pillar, serve to steady the platform. By turning the keys these wires may be kept taut, and the platform, floating with a certain amount of constraint, behaves as a massive pendulum with its bob partly immersed in the water.

The trough, which contains the interferometer liquids, is a closed rectangular vessel, $40 \times 10 \times 6$ cm. in size. One end is formed by a prism of equilateral section, attached to the sides of the trough, with one of its surfaces inclined at an angle of 13° (for water) to the vertical, as shown in the figure. The collimated beam, which is reflected upwards, enters the first



face of the prism normally, and after total reflection at the second face enters the liquid after passing out normal to the third face. This arrangement effects a considerable saving in light and is very convenient in practice. To prevent stray light in the field of the telescope, caused by the capillary curvatures of the liquid in contact with the prism, a wide slit with adjustable

jaws is mounted in front of the aperture in the trough and restricts the collimated beam to a suitable width in the central region. The trough is completely enclosed, to prevent the disturbing effects of air currents, and the emergent light passes out through a thin mica window on the end opposite to the prism.

With this arrangement experiments were made successfully with a layer of water resting on mercury. During the daytime the heavy traffic in the near neighbourhood of the laboratory and the movement of students were disturbing. But during the quieter hours of the night the fringes were found to be remarkably steady notwithstanding the disturbing effect of the sea waves, 300 yards away. The fringes are found to be remarkably sharp on quiet days. The success of the arrangement has been proved beyond a doubt and, notwithstanding its complexity in its present form, its advantages over the glass plate are evident.

The resolving power R of a parallel plate may be expressed* as

$$R = 2\mu n \cos r,$$

where μ is the refractive index for the wave-length used,

t is the thickness,

r is the critical angle,

and n the number of emergent beams.

But
$$n = \frac{L}{2t} \cot r,$$

where L is the length of the plate; and

$$\mu = \frac{1}{\sin r}. \quad \text{Hence } R = L \cot^2 r,$$

i.e., the resolving power is directly proportional to the length. Thus for securing high resolving powers we may use the maximum length which the quantity of light and the transparency of the liquid will permit. The above relation shows that the resolving power is independent of the thickness.

Further, in a system of interference bands formed by a parallel plate, the order of interference N is given by the relation

$$N = \frac{2\mu t \cos r}{\lambda},$$

where λ is the wave-length of light in question. Differentiating, we get

$$dN = -\frac{2\mu}{\lambda} t \sin r \, dr,$$

* The elementary theory given here is recognised as inadequate, and my attention has been called to the detailed theory given in Gehrcke's book, 'Anwendung der Interferenzen,' 1906, and Kolacek's paper in 'Ann. der Phys.,' vol. 39, p. 1431 (1912).

and for two thicknesses of glass t_1 and t_2 we get the two relations

$$\frac{dN_1}{dr_1} = -\frac{2\mu}{\lambda} t_1 \sin r$$

and

$$\frac{dN_2}{dr_2} = -\frac{2\mu}{\lambda} t_2 \sin r.$$

Therefore

$$\frac{dN_1}{dr_1} \bigg/ \frac{dN_2}{dr_2} = \frac{dr_2}{dr_1} = \frac{t_1}{t_2} \text{ since } dN_1 = dN_2 = 1.$$

But

$$\frac{\sin i}{\sin r} = \mu > 1,$$

where i is the angle of emergence corresponding to the angle of refraction r .

Therefore, the corresponding di_2/di_1 which expresses the ratio of the separation between the two lowest order bands in the two cases is given by the relation

$$\frac{di_2}{di_1} = k \frac{t_1}{t_2},$$

where k is some factor of numerical value greater than unity.

This shows that the thickness of the plate affects the separation between the individual bands in the interference pattern, and it is seen that the separation varies inversely as the thickness of the plates forming them. In practice it is advantageous to have the individual bands widely separated to secure high resolving powers and hence the thinner the plate the better. But with glass for purposes of mechanical strength and rigidity the thickness for a given length cannot be reduced beyond a certain limit, while with the liquid plate the need for such limitation does not enter. In fact it is found in practice that the liquid plate gets steadier the thinner it is. The limit is then set by the curvature due to capillarity. The greater the amount of light that can be introduced into the plate the stronger the multiple reflections and the sharper and brighter the fringes. If the amount of light introduced into the plate be increased by increasing the thickness, the decreased separation between the fringes is disadvantageous. It is preferable to introduce more light into a plate by increasing its width, a course obviously less costly in the case of a layer of water than in the case of optically worked glass.

Considered in all these aspects, notwithstanding the complexity of the suspension, its advantages are clear and doubtless the arrangements can be further simplified.

In conclusion I must express my indebtedness to Prof. R. Ll. Jones, of the Presidency College, Madras, for his kind and sympathetic help in the prosecution of this research.
